ROTATIONS OF WHEAT, BARLEY, CANOLA AND HAY ON A DARK BROWN SOIL IN WEST CENTRAL SASKATCHEWAN.

S. A. BRANDT[1] and R. P. ZENTNER [2]

[1]Experimental Farm, Research Branch, Agriculture Canada, Scott, Saskatchewan, Canada SOK 4AO
[2]Research Station, Research Branch, Agriculture Canada, Swift Current, Saskatchewan, Canada

ABSTRACT

In a long term study, yield of wheat or canola on summerfallow was influenced very little by rotation. On the other hand, yield of wheat or barley grown on stubble was affected by rotation. Yield of wheat on canola stubble was generally higher than on wheat stubble. Yield of hay was highly variable from year to year. Yield of canola relative to wheat was much higher during 1980 to 1991 than reported for 1972 to 1979. Furthur, yield variability of canola between years was much lower during 1980-91 than 1972-79. In wheat monoculture rotations, yield variability increased as summerfallow frequency decreased. In rotations of canola with cereals and/ or a forage the same trend did not occur. The influence of these results on economic viability of rotations where summerfallow is practiced less frequently is discussed.

INTRODUCTION : A number of cropping options are available for use in rotations in the dark brown soil zone of western Canada. Unlike the brown soil zone, available water is less limiting and permits production of a range of cereal, oilseed and pulse crops. However, successful crop production is still very reliant upon efficient use of moisture. Because of limited moisture and economic considerations, summerfallow is practiced on 35% of annual cropland in this zone (Campbell et al. 1986). Predominant rotations in the area are based on summerfallow followed by two years of cropping (Kirkland and Brandt 1984).

Several crop rotation studies have been conducted on the Canadian prairies (Campbell et al. 1990; Freyman et al. 1982; Austenson et al. 1970). Only a few of these studies were done on dark brown soils and most dealt mainly with wheat production. Few studies included canola (rapeseed), an important crop on northern dark brown soils. Production of canola in rotation with cereals presents a number of potential advantages for weed and disease control and improved economic returns. However, research to more clearly define the role and place of canola in rotations has not been conducted previously

The main objectives of this study were to evaluate several rotations containing various combinations of canola, wheat, barley, alfalfa and summerfallow on grain and forage yield and quality, soil moisture storage and utilization, as well as changes in soil quality and incidence of weeds and diseases. This paper discusses the influence of rotation on grain and forage yieldand moisture use during 1980 to 1991.

MATERIALS AND METHODS: The study was initiated on an Elstow and shallow Elstow loam soil (Clayton and Ellis 1952), a dark brown chernozem with an organic nitrogen content of 0.2 percent (0 to15 cm depth) and a surface pH of 6.8 (paste method). The nine rotations studied during 1980 to 1991 included 2 year rotations of fallow with canola (*Brassica campestris* L.) or wheat (*Triticum aestivum* L.), several 3 year rotations of canola wheat and barley (Hordeum vulgare L.) with fallow , a 4 year , and a 6 year rotation of grain crops with alfalfa (Medicago sativa L.) hay (Table 1). Rotations were arranged in a randomized complete block design with four replicates and all phases of each rotation present each year, using a plot size of 7.3 by 30.4

Commercial farm equipment was used to perform most cultural and tillage operations, with actual operations varying slightly from year to year depending on soil and climatic conditions. Tillage intensity declined over time, with an average five operations on fallow in early years, reduced to four operations in latter years. Initially fall tillage with a cultivator or tandem disc was always performed on stubble, while in recent years fall tillage was usually eliminated. During 1980 to 1986,seedbed preparation typically consisted of early spring tillage followed by tillage just prior to seeding, both with a cultivator. Tine harrows were generally used with the second operation. A rodweeder was used in place of the cultivator for the second operation on plots to be seeded to canola.From 1987 to 1991 only one preseeding tillage operation was used. Seeding was done with a double disc press drill from 1980 to 1986 and a high clearance hoe drill from 1987 to 1991. Wheat was typically sown near May 14, Barley May 19 and canola May 26. Post-seeding harrowing was performed for seedling weed control during 1980 and 1981, but not thereafter.

Table 1. Crop rotations utilized in a crop rotation study at Scott, Sask., 1980-1991.

	Rotation	Designation
1	Fallow-canola	F-C
2.	Fallow-wheat	F-W
3.	Fallow-canola-wheat	F-C-W
4.	Fallow-wheat-wheat	F-W-W
5.	Fallow-canola-barley	F-C-B
6.	Fallow-wheat-barley	F-W-B
7.	Fallow-canola-barley-hay	F-C-B-H
8.	Fallow-canola-wheat-barley-hay-hay	F-C-W-B-H-H
9.	Continuous wheat	Cont-W

Plots were sown at the recommended rates of 100, 70, 7, and 7 kg/ha for spring wheat, barley (*hordeum vulgare* L.), canola and alfalfa (*Medicago sativa* L.) respectively.

Fertilizer application rates for all cereal and oilseed crops were based on general recommendations of the Saskatchewan Soil Testing Laboratory. Crops grown on fallow received an average of 6 kg/ha of N plus 28.5 kg/ha of P2O5 and crops grown on stubble in all rotations received an average 39 kg/ha of N broadcast incorporated from 1980-84 and banded from 1985-90 along with 5 kg/ha of N and 23 kg/ha of P2O5 seed placed. Continuous wheat had an additional 5.5 kg/ha of N from 1985-1991 banded as for other stubble treatments. Forage crops received no fertilizer.

Herbicides were used for in crop weed control as required using recommended methods and rates. For broadleaf weed control in cereals, 2,4-D, MCPA and bromoxynil were typically used . For wild oat control in cereals diclofop-methyl was used each year . Trifluralin was routinely applied in the previous summer for the following canola crop. From 1980-1991, 2,4-D B or MCPB were applied for broadleaf weed control in barley underseeded to alfalfa. Herbicides were not applied to forage plots in the years of utilization as forage.

Breaking of the forage plots was done with a heavy duty cultivator equipped with spikes and was usually completed by July 15

Grain yields were determined by harvesting a 3.0 m x 30.4 m swath of crop with a commercial combine and weighing the grain harvested during 1980 to 1982 and by harvesting a 1.2 m x 30.4m area with a small plot combine during 1983-1991. Remaining grain was harvested with a commercial combine and residues were distributed onto the plots from which they originated.

Statistical comparisons among treatment means were made using analysis of variance procedures (with years, replicates, and rotations as factors) (Little & Hills 1978) and the Least Significant Difference (LSD P= 0.05) test of significance.

RESULTS AND DISCUSSION : Wheat yield on fallow was similar for all rotations over all years (table 2). Weed control was very good in all rotation years and it is probable that summerfallowing masked any rotational effects on weed populations or disease levels. Rotations did not affect spring soil moisture. Similar results were reported for adequately fertilized wheat on fallow in grain crop rotations in the Brown (Zentner and Campbell 1988) Dark Brown (Austenson et al. 1970) and Black (Zentner et al. 1987, Zentner et al. 1990) soil zones of Saskatchewan.

Wheat yield on fallow generally exceeded stubble yield, although there were exceptional cases where stubble yield equalled fallow yield. Wheat yield on canola stubble generally exceeded yield in rotations where wheat was grown on wheat stubble, and continuous wheat was the lowest yielding. The year by rotation interaction was significant. From 1980 to 1986, more preseeding tillage was done than in latter years and stubble wheat yields were only slightly affected by rotation (Table 3). However, from 1987 to 1991 with minimum tillage, rotation effects on yield were much greater. During 1987 to 1991, increased incidence of leaf and spike diseases due to *Septoria spp* and tan spot (*Pyrenophora tritici-repentis* [Died] Drechs) were noted. Reduced tillage left greater quantities of crop residue on the soil surface and where they harbored overwintering disease inoculum, could result in greater infection of the succeeding crop. Higher yield of wheat following canola than following wheat has been reported at Loon Lake, Saskatchewan (Brandt 1981) and at Portage La Prairie, Manitoba (Austenson 1978).

The coefficient of variability (CV) for yield over years provided an index of year to year yield variations. In this study, CV's averaged 29% for fallow and stubble wheat, although the values for continuous wheat were higher (34%) and for F-C-W were lower (24%). CV's of 29 and 35% were reported for wheat on fallow and stubble respectively in the brown soil zone (Campbell et al. 1983). In the black soil zone, CV's of 24 and 37% (Zentner et al. 1987) or 33 and 41% (Zentner et al 1990) were reported for fertilized wheat on fallow and stubble respectively. These previous studies indicated that yield variability was greater for wheat on stubble than on fallow, in contrast with results reported here. All of these studies included a number of years prior to 1980. It is likely that improved weed control and cultural practices for wheat on stubble since 1980 have reduced year to year variability. Most notable among improved cultural practices is the use of reduced seedbed tillage to conserve moisture, ensuring uniform crop establishment on stubble. Yield variability on stubble may be further reduced by growing wheat on canola rather than on wheat stubble.

During 1980-91, canola yield was similar for all rotations (table 2). Weed control was not always adequate as on several occasions stinkweed (*Thlaspi arvense* L.) caused significant yield losses particularly in the F-C and F-C-W rotation phases, and was a factor in the significant year by rotation interaction.

Coefficients of variability for yield ranged from 20 to 25% and were generally lower than for wheat grown on fallow. This is in contrast to results of the preceding period 1972-79 (Campbell et al. 1990), when average CV's for canola yield were 53 %, almost double the CV for wheat on fallow during the same period. Similarly high CV's for yield of canola were reported for black soils (Campbell et al. 1990).

The performance of canola relative to wheat improved dramatically during 1981-90 compared with 1972-79. During 1972-79 canola yield was 33% of wheat on fallow (Campbell et al. 1990), but increased to 49% during 1980-91.

While some of the increase in yield and reduced yield variability of canola relative to wheat can be attributed to improved varieties, they can account for only a small proportion of these improvements. The major factors contributing to improved canola production have been better weed control and more suitable seedbed preparation practices that have led to more uniform and competitive crop stand.

Spring soil moisture tended to be higher for the F-C and F-C-B-H rotations. This may have resulted from higher residual soil moisture following the canola crop in the F-C rotation and the long fallow (22 months) period in the F-C-B-H rotation. However, differences in SpSM were too small to have a significant impact on yield in most years.

Barley grown on canola stubble in the F-C-B-H rotation yielded more than in other rotations (Table 2). Most of the yield increase could be attributed to higher SpSM for barley in this rotation. Enhanced SpSM may have been a residual effect of the long fallow period following breaking of the forage crop. SpSM was also increased in the

Table 2. Yield, yield variability and available spring soil moisture (SpSM) for wheat, canola, barl:ey and hay during 1980 to 1991 in a crop rotation study at Scott, Sask.

Rotation	Mean yield		SpSM
	kg ha^{-1}	CV (%)	mm
F - <u>W</u> *	3000	29	154
F - <u>W</u> - W	3080	30	164
F - <u>W</u> - B	3060	27	160
LSD (P=0.05)	ns		ns
F - W - <u>W</u>	2160	31	113
F - C - <u>W</u>	2340	24	115
F - C - <u>W</u> - B - H- H	2290	27	117
Continuous <u>W</u>	1890	34	94
LSD (P=0.05)	94		8
F - <u>C</u>	1460	22	167
F - <u>C</u> - W	1470	24	155
F - <u>C</u> - B	1460	25	156
F - <u>C</u> - B - H	1500	20	167
F - <u>C</u> - W - B - H - H	1410	23	153
LSD (P=0.05)	ns		8
F - C - <u>B</u>	3010	30	113
F - W - <u>B</u>	2900	28	114
F - C - <u>B</u> - H	3210	23	130
F - C - W - <u>B</u> - H - H	2790	34	107
LSD (P=0.05)	126		9
F - C - B - <u>H</u>	1920	60	122
F - C - W - B - <u>H</u> - H	1750	63	111
F - C - W - B - H - <u>H</u>	1630	51	96
LSD (P=0.05)	151		6

* values in table are for the underlined crop.

Table 3. Yield of wheat grown on canola and wheat stubble in crop rotation studies at Scott, Sk. with conventional tillage during 1980-86 and with minimum tillage, 1987-91.

Treatment	Yield (kg/ha) 1980-86	1987-91
Wheat on canola stubble		
- fallow-canola-wheat rotation	2440	2210
Wheat on wheat stubble		
- fallow-wheat-wheat rotation	2400	1820

canola year of the F-C-B-H rotation. Barley yields were lowest in the F-C-W-B-H-H rotation phase. In this rotation phase, weed competition was generally greater than in barley grown in other rotations. Yield variability (CV) for barley was similar to wheat. The CV was lower for the F-C-B-H than for other rotations, possibly due to generally higher SpSM.

Forage yields were generally low and highly variable from year to year, due in part to variability in stand establishment. Generally low forage yields compared with grain yields probably reflects precipitations distribution at Scott. Precipitation during May and June was more like conditions typical of the Brown soil zone while July precipitation is more similar to most of the Black soil zone. This distribution of precipitation was more favorable to grain than forage crops, as forages generally begin growth earlier and require more moisture during May and June than grain crops.

During the course of this study, annual grassy weed numbers were very low in cereals following canola, reflecting excellent control with trifluralin. These weeds were more abundant in cereals only rotations, particularly continuous wheat. On a number of occasions, herbicides for grassy weed control were not required for cereals on canola stubble but were required in cereals only rotations in almost all occasions.

Stinkweed numbers in canola tended to increase as the frequency of canola in the rotation increased (table 4). This weed is quite costly to control in canola, but relatively inexpensive in cereals. Incidence of blackleg in canola during 1990 showed a similar trend to increase as canola frequency increased.

Table 4. Stinkweed and blackleg in canola in crop rotations at Scott

Rotation	Stinkweed	Blackleg
Fallow-canola	190	43.5
Fallow-canola-wheat	129	9.5
Fallow-canola-barley	27	9.0
Fallow-canola-barley-hay	23	8.0
Fallow-canola-wheat-barley-hay-hay	50	4.0

Stinkweed numbers based on counts made in 1981, 1985, and 1990 (plants/sq. m).
Blackleg based on counts made in 1990 only (% infected plants).

Economic analyses of crop rotation studies have shown that one of the advantages of frequent fallowing in wheat monoculture rotations is a reduction in year to year variability in net returns, due in large measure to lower yield variability (Zentner and Campbell, 1988. Zentner et al 1988). We calculated coefficients of variability for yields on a rotation basis to determine whether rotation of different crops would result in a change in yield variability. Coefficients of variability were greater for continuous wheat than for fallow containing rotations (table 5). However, within fallow containing rotations, yield variability was less dependent upon fallow frequency than on the mix of crops grown. CV's were lowest for the fallow-canola-wheat and fallow-canola-wheat-barley-hay-hay rotations than for the monoculture wheat rotations. Rotations of canola or wheat with barley and monoculture canola had intermediate CV's.

SUMMARY

Rotation had little effect on yield of wheat or canola grown on fallow. Fallow likely acts to mask rotational effects on weeds, diseases, moisture and nutrients. Rotation effects on yield were most evident on stubble, in particular where wheat on wheat stubble declined with minimum tillage due to increased disease losses.

Benefits of having canola present in rotation with cereals include reduced grassy weed control costs, reduced cereal leaf disease losses and more stable overall yields from year to year. Similarly, there are benefits to having cereals in rotation with canola; improved control of some annual broadleaf weeds, reduced disease incidence and improved yield stability.

From the viewpoint of conserving soil, it is desireable to reduce summerfallow and tillage. It is apparent that the risk of economic failure may be much greater in cereal monoculture rotations than in canola-cereal rotations.Developing appropriate rotations of broadleaf and cereal crops is a critical component of developing soil conserving grain crop production systems for the dark brown soil zone.

Table 5. Mean annual yield (kg ha^{-1}) of grain plus forage calculated on a rotation basis, and coefficients of variability over years for nine rotations of wheat, canola, barley and hay at Scott, Sask. during 1980-91.

Rotation	mean yield	coefficient of variability (%)
Fallow-canola	718	22
Fallow-wheat	1501	26
Fallow-canola-wheat	1273	19
Fallow-wheat-wheat	1746	25
Fallow-canola-barley	1496	23
Fallow-wheat-barley	1985	25
Fallow-canola-barley-hay	1748	24
Fallow-canola-wheat-barley-hay-hay	1555	19
Continuous wheat	1895	31

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